Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 10, October-2023

Analysis of the Progression of the Collapse of Regular and irregular RCC Buildings

Mr. SOUVIK MAJI
Dr. Minangshu Baidya
Techno India University, M.Tech Scholar, Department of Civil Engineering, Salt Lake City, Kolkata(W.B), India
Techno India University, Professor and Head of Department, Department of Civil Engineering, Salt Lake City, Kolkata(W.B), India

Helping Juniors:
1. Mr. Anik Pramanik
2. Miss. Laboni Saha

Abstract: **Analysis of the progressive collapse of three 20-story conventional buildings with Using STAAD.Pro V8i SS6 software, linear elastic static and nonlinear static techniques are used to analyze RC frame buildings without a central atrium and with uneven shapes. By using stepped-type geometry along a shorter bay, irregularity is created. Each step of the study is carefully examined, and DCR values are quantified, briefly stated with benefits and drawbacks, and compared considerably in accordance with GSA recommendations. Investigating the structural linear and nonlinear behavior of various building structures is the goal of this research, which also aims to create design guidelines and tactics for creating economically sound structures that are resistant to progressive collapse. Rotation and displacement of plastic hinges are observed using nonlinear static analysis, coupled with the percentage of GSA load attempt, as a result of the rapid removal of the principal load-bearing column member of the ground floor from various places.**

Keywords Progressive collapse _ LSA _ NSA _ Multi-storied RCC building GSA

1. INTRODUCTİON:

When an important basic member of a structure collapses due to natural or artificial disasters, the loads from the lost member are transferred to connecting members, which then fail as a result of the redistributed loads. This process continues until a disproportionate amount of the structure is damaged or collapses. Localized damage that causes progressive collapse is referred to as starting damage. Progressive collapse is a nonlinear phenomenon in which structural components are stretched past their elastic breaking point. The goal of this study is to develop a methodology for assessing a structure's propensity for gradual collapse utilizing various analysis approaches. For examining the structure, static linear analysis and static nonlinear (Pushover Analysis) methods are compared.

1.1 Building Geometry:

For study, three 20-story RC Frame buildings one without an atrium, one with an atrium, and one stepped along a shorter span are taken into consideration (Fig. 1).All buildings are 40 m x 32 m in size, with 4 m x 4 m panels, and a 57 m overall height. The lowest three floors, which are used for parking, are 2 m tall, while the top 17 floors have storey heights of 3m.

With a 150 mm slab thickness, the size of the beam and column are assumed to be 250 mm x 300 mm and 450 mm x 450 mm, respectively. Fe415 & Fe250 steel grade and M25 concrete are employed as material attributes. For the design of a building in accordance with IS 456-2000, the dead load of a structure with walls around the building's perimeter and the live load of 3 kN/m2 are taken into consideration.

The size of the atrium is 16 m 16 m for the structure with a central atrium, but stepping is done along a shorter span after the 7th and 12th storeys in a stepped construction.

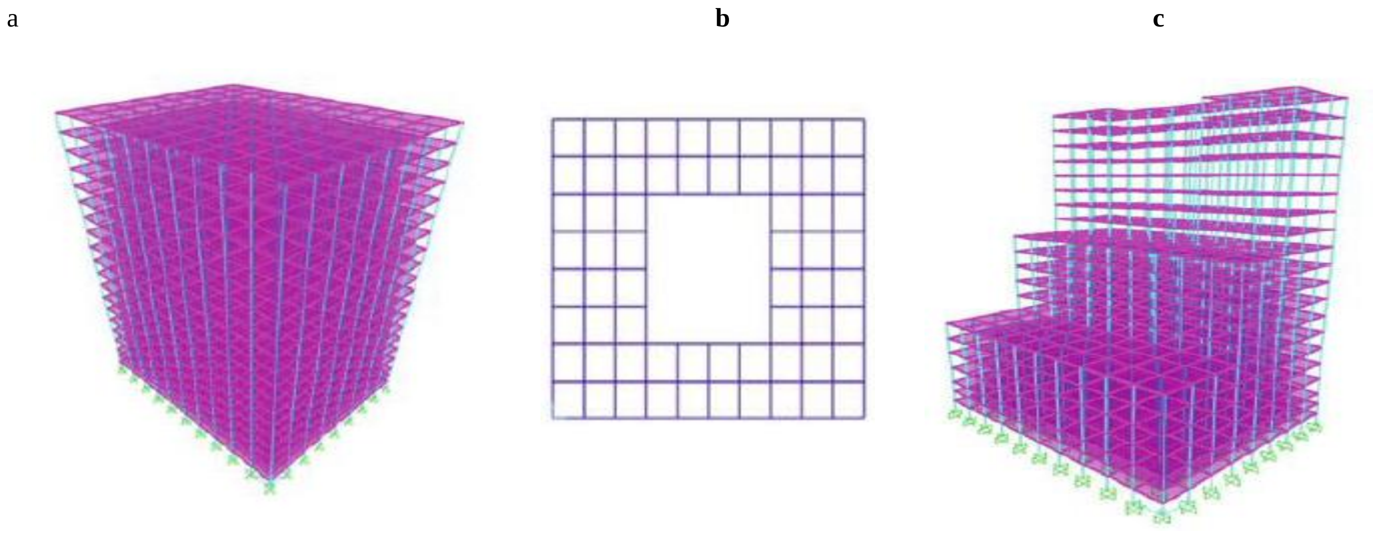


Fig. 1 (a) Regular building with natrium. (b) Regular building plan with atrium &
(c) Irregular Building with stepped elevation

2.0 LİNEAR STATİC ANALYSİS:

Different scenarios of column removal from the stated location of the ground floor are taken into account in geometry in linear static analysis (LSA) and analysis with the gravity load provided by imposed on the structure has been done. After analyzing demand at key areas in each building, the Demand Capacity Ratio (DCR) is determined for each structural member based on the analysis's findings. This analysis' generated DCR values will help determine the likelihood of gradual collapse in the end.

The structure's vertical load case is used as the starting point for a static linear analysis.

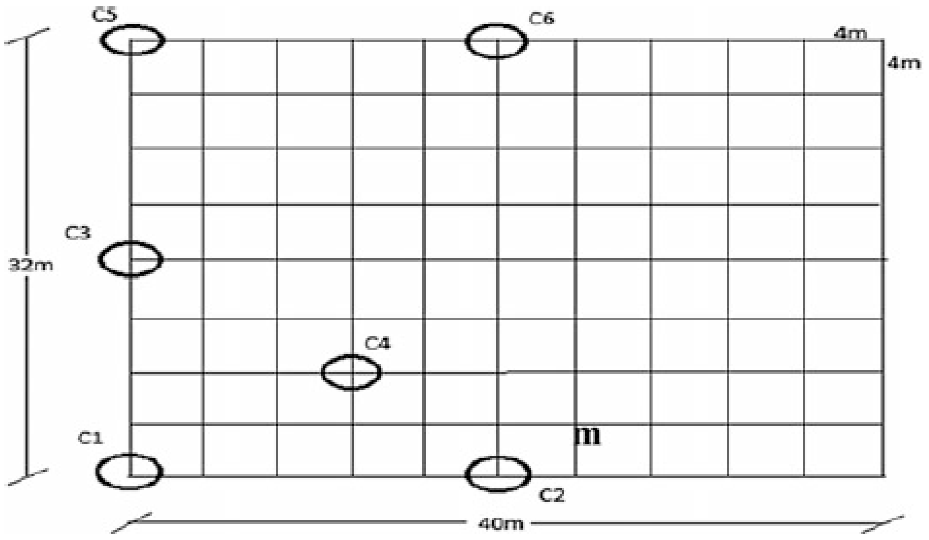
$$\text{LOAD} = 2\,(\text{DL} + 0.25\ \text{LL})$$

When using the linear analytic approach to determine the failure of key structural members, the GSA 2003 advocated using the DCR, or the ratio of member force to member strength.

$$\text{DCR} = \text{QUD} / \text{QCE}$$

Where QCE is the anticipated maximum capacity of the component (moment, axial force, shear, etc.), and QUD is the influencing force (demand) deduced in the component (moment, axial force, shear, etc.). After analysis and design, the capacity of the member is estimated at any section in accordance with IS456:2000 using the obtained reinforcing data.

The GSA rules' allowable DCR values for major and secondary structural parts are



According to GSA regulations, the acceptable DCR values for major and secondary structural members are DCR< 2.0, DCR <1.5 for regular buildings, and DCR< 2.0 for irregular buildings. A member is deemed to have failed if their DCR at any section exceeds the predetermined acceptable requirements for shear and flexure. The procedures used in LSA in accordance with GSA 2003 guidelines.

- To calculate the capacity of the member in flexure, space models for various structural geometries are produced, then concrete design and reinforcement check. During PCA, the strength increase factor is taken into account.
- DCR values are obtained before executing LSA by computing demand and capacity for each member taking into account a column loss scenario by removing ground floor columns from the designated places as indicated above one at a time.
- These calculated DCR values are compared to the equivalent floors of the structure reported in GSA 2003 to see if they meet the acceptance standards.

Figs. 3, 4, and 5 display the current designs for various RC frame building types with no column removal and column removal from places C1, C2, C3, and C4. All column removal scenarios exhibit the asymmetrical distribution of moments from the top floor to the fallen ground floor column, which increases the likelihood that the progressive collapse will fail.

3.0 STATİC NONLİNEAR ANALYSİS (NSA):

In NSA, the nonlinear behavior of structural components that reach maximum load (load-controlled) or maximum displacement (displacement-controlled) by applying increasing loads in steps is investigated. "Pushover analysis" is another name for NSA. This approach under lateral load conditions can be used to quantify the ductility of structural components. It is a measurement that is calculated as the ratio of the maximum to the yield deformations. In general, a structure will perform better during an earthquake if it can achieve a high degree of ductility. Pushover analysis engages numerous structural components in well-designed structures and typically ensures balanced construction (for instance, strong columns and weak beams). Since structural performance under typical service loads is assessed while analyzing for the possibility of progressive collapse, vertical pushover analysis is often load-controlled.

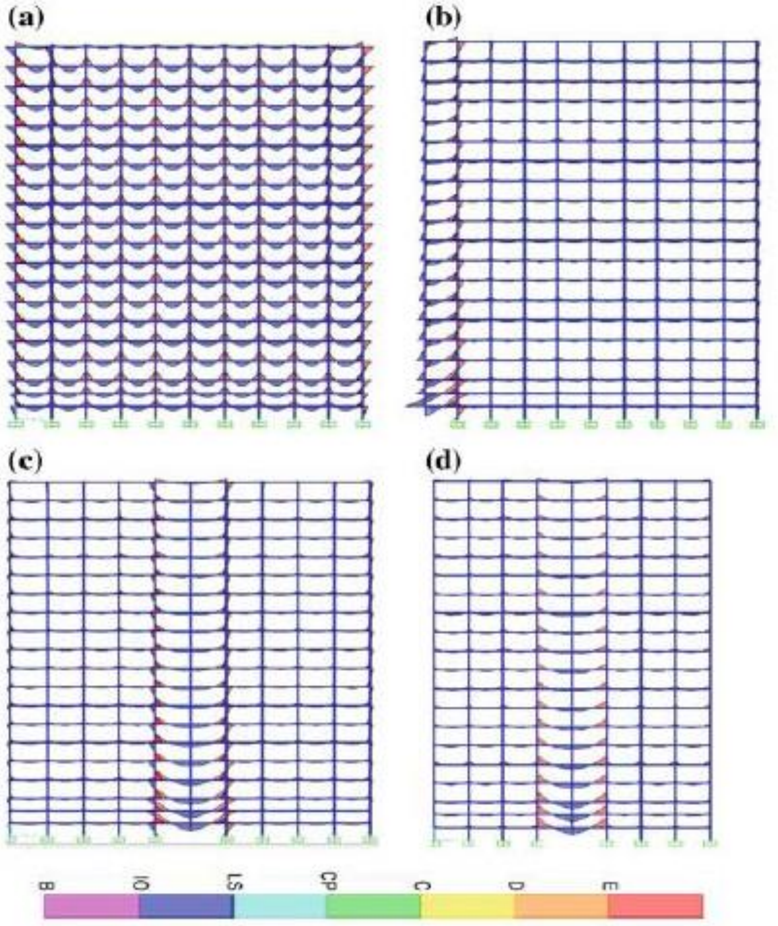


Fig. 3 Moments distribution in regular building when (a) No column removed, (b) Column C1 removed,(c) Column C2 removed, (d) Column C3 removed

The steps followed in NSA according to GSA 2003 guideline

- To calculate the member's capacity in flexure, space models for various structural geometries are produced and sequentially put through concrete design and reinforcing verification. The PCA takes into account the strength-increasing component.
- STAAD.Pro V8i SS6 employs Tables 5 and 6 of FEMA-356, where P-M2-M3 hinges are assigned to columns at both ends before doing NSA and M3 and V2 plastic hinges are assigned at both ends of beam before performing NSA.
- After specifying the load combination in accordance with GSA for the nonlinear scenario, perform the analysis. Until failure, hinge structures are observed.

The static nonlinear evaluation load case is the same as the static linear analysis load scenario. Each frame element is given automatic hinge properties for nonlinear analysis.

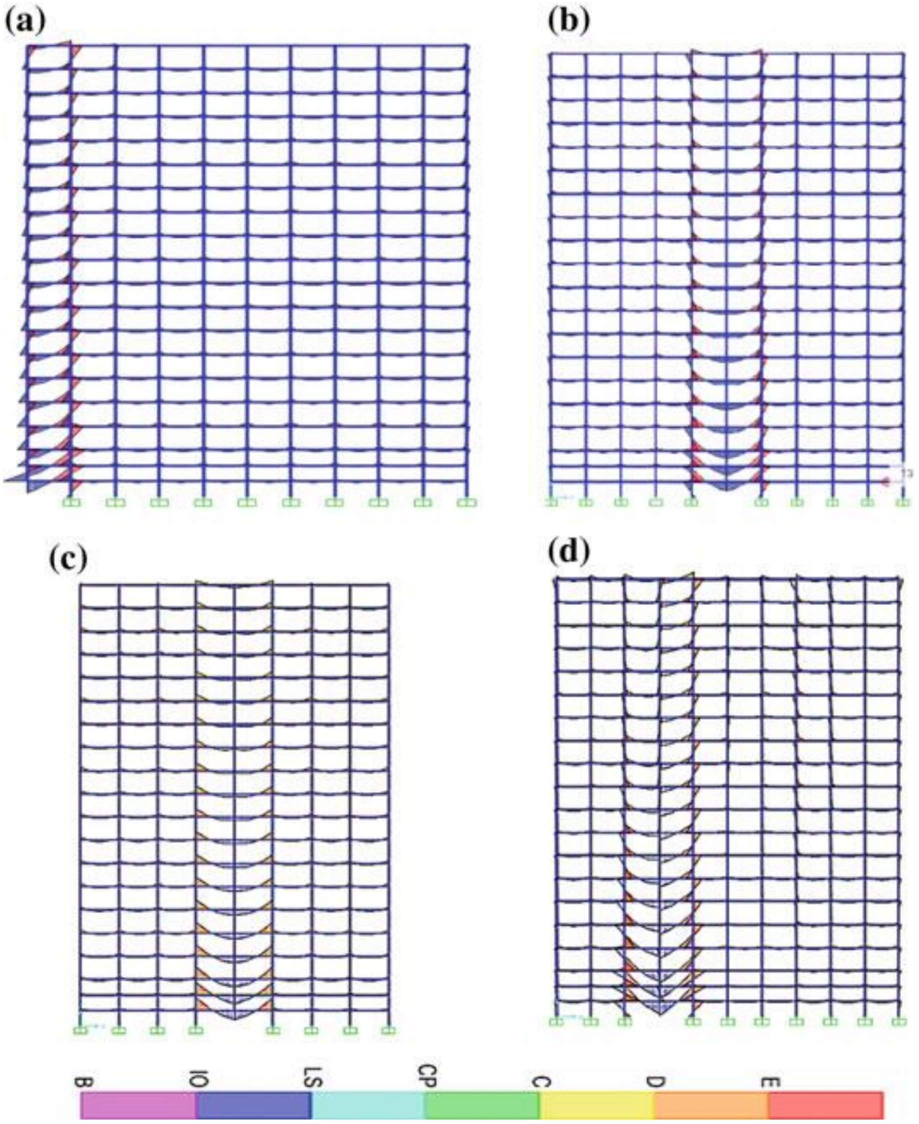


Fig. 4 Moments distribution in building with atrium when, (a) column C1 removed, (b) column C2 removed, (c) column C3 removed, (d) column C4 removed.

Figures 6, 7, and 8 depict a hinge that is developed along a longer bay in a transverse and horizontal direction in various building geometries.

The pushover analysis results shown in Figs. 6, 7, and 8 reveal that the corresponding joints over a collapsed column exhibit excessive deformation; therefore, before choosing to perform a pushover analysis, it should be mandatory to ensure that the beam-column joint has sufficient strength and ductility to ensure the formation of permissible hinges.

4.0 RESULTS :

4.1 DCR Values :Below, in Figs. 9, 10, and 11, are plots showing DCR values for regular buildings, buildings with atriums, and irregular buildings with stepped elevations, respectively, with the number of storeys on the abscissa.

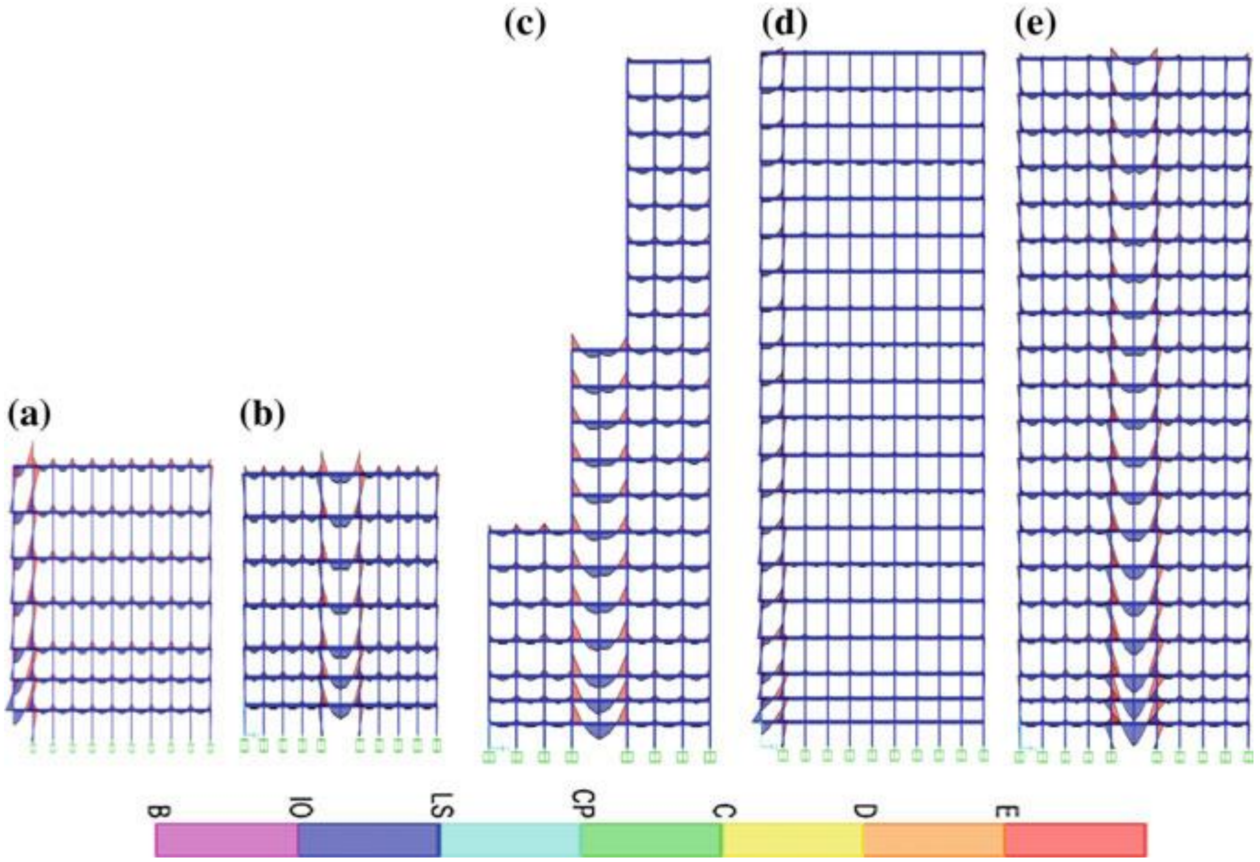


Fig. 5 Moments distribution in irregular building with stepped elevation along shorter span when (a) column C1 removed,(b) column C2 removed, (c) column C3 removed, (d) column C5 removed, (e) column C6 removed

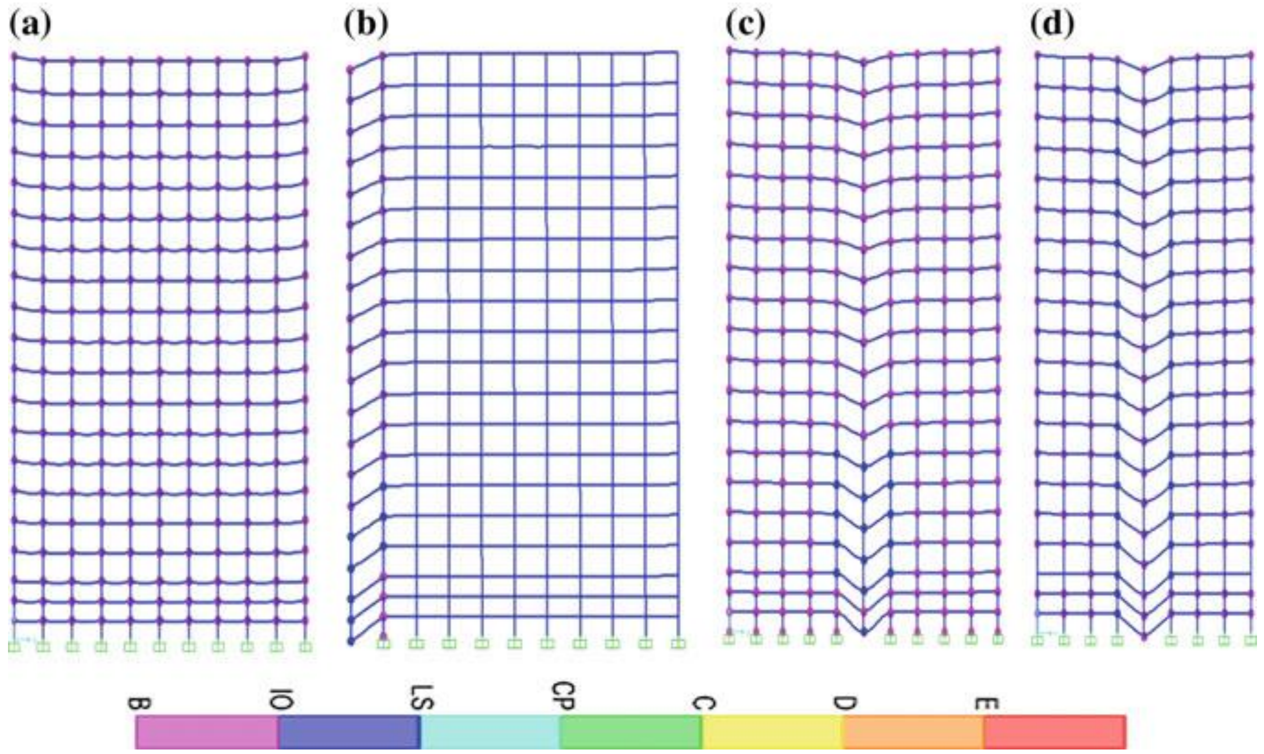


Fig. 6 Hinges formation in regular building when (a) no column removed, (b) column C1 removed,
(c) Column C2 removed, (d) column C3 removed

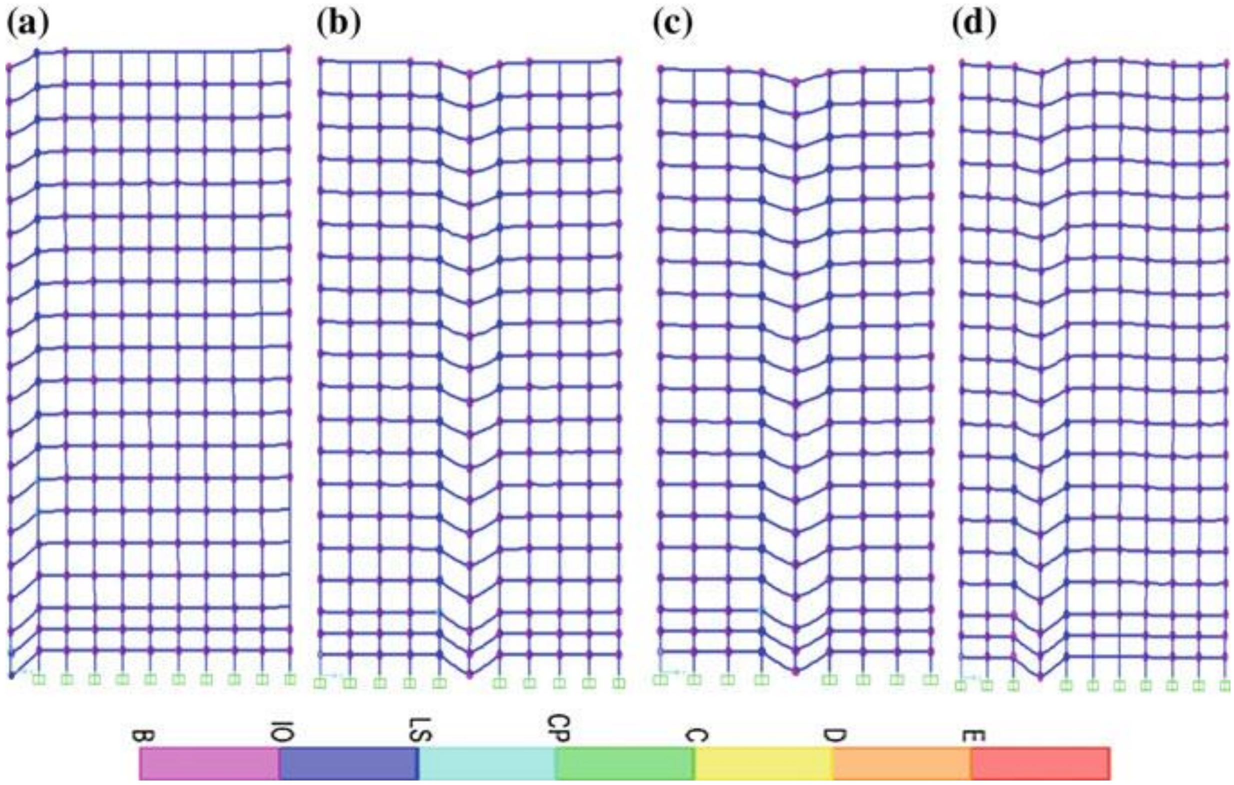


Fig. 7 Hinges formation in building with atrium when, (a) column C1 removed, (b) column C2 removed, (c) column C3 removed, (d) column C4 removed

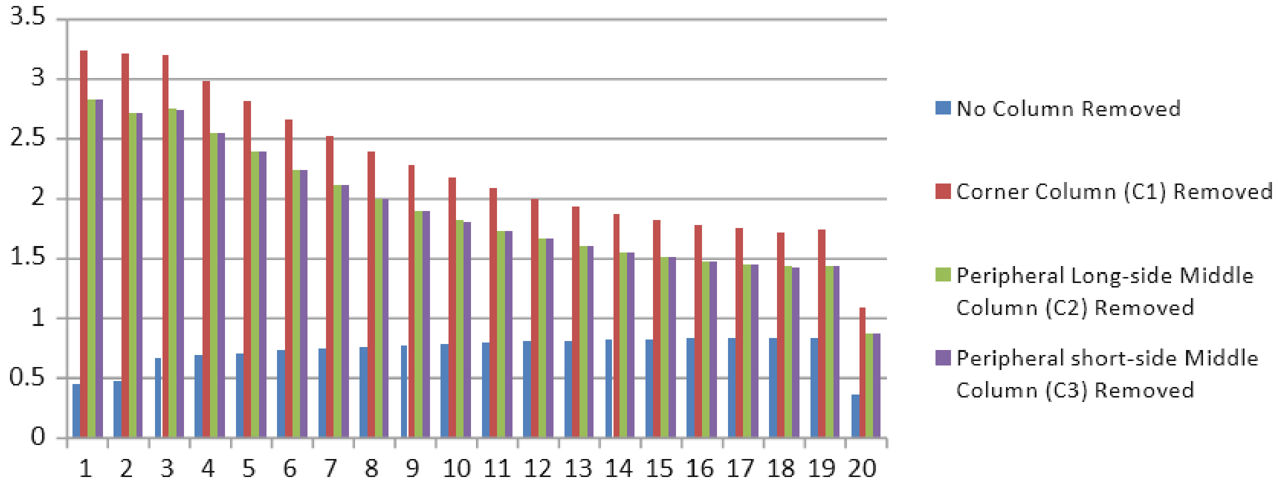


Fig. 9 Plot of DCR values with number of storeys in regular building

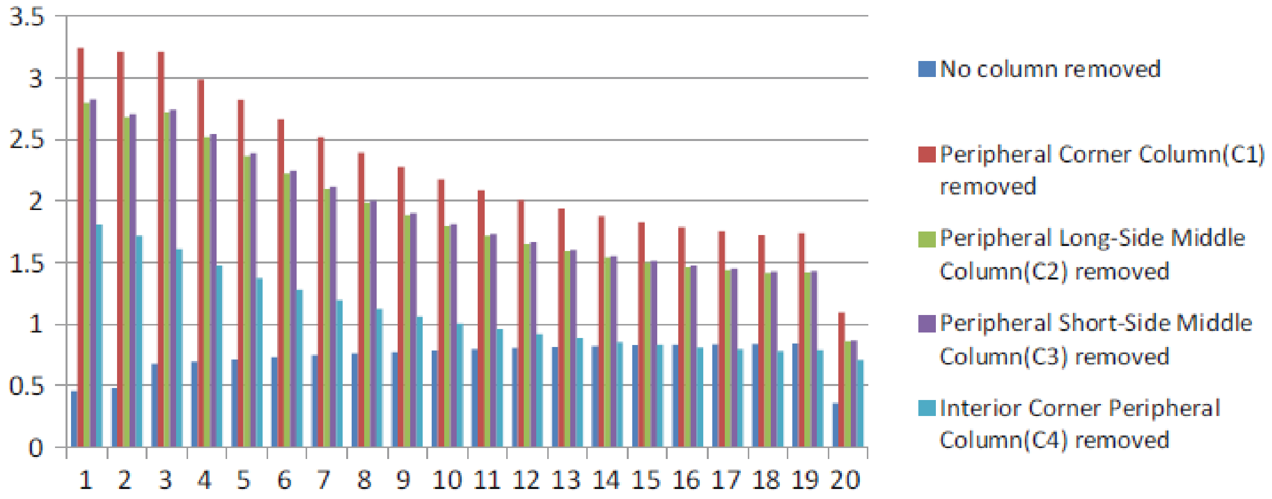


Fig. 10 Plot of DCR values with number of storeys in regular building with atrium

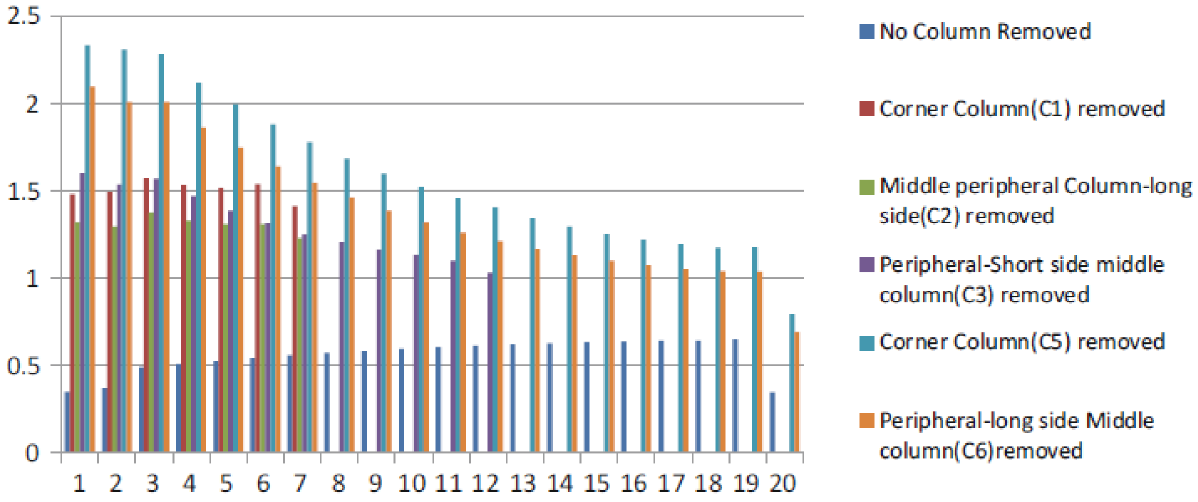


Fig. 11 Plot of DCR values with number of storeys in irregular building

The plots that are displayed reveal that corner column collapses in all buildings exhibit critical results, which are then followed by cases of peripheral column removal along shorter bays because the DCR values exceed the permitted limits in accordance with GSA requirements [8]. In each situation, the fully damaged column, which continues to support the top level, is where the failure of the beam-column joint will start. A-column joints of the lower 12 stories of the specified building structures are given extra care in the design in order to avoid progressive collapse at these crucial spots.

4.2 PERCENTAGE GSA LOAD ATTEMPT

The ratio between the total load applied and the sum of the reactions measured at the structure's supports is used to calculate the percentage of load attempts. In NSA, a structure is deemed to have adequate resistance to progressive collapse if the weight it can support after a column is lost in each scenario reaches 50% [7].

The percentage load attempts in all of the normal building's column removal scenarios are quite close to the 50% permitted limit. This is because tall buildings have heavier dead loads than buildings with atriums or stepped raised buildings (Tables 2 and 3), which have lighter dead loads. The collapse of the corner column the full height building span causes the crucial value of the percent GSA load attempt in irregular buildings with stepped elevations.

Table 1 GSA load attempt in NSA for regular building

Column removal case	**GSA loading condition**	**%GSA load attempt**
Column C1	2(DL + 0.25LL)	66.73
Column C2	2(DL + 0.25LL)	67.78
Column C3	2(DL + 0.25LL)	60.16

Table 2 GSA load attempt in NSA for regular building

Column removal case	**GSA loading condition**	**%GSA load attempt**
Column C1	2(DL + 0.25LL)	87.09
Column C2	2(DL + 0.25LL)	73.65
Column C3	2(DL + 0.25LL)	75.78
Column C5	2(DL + 0.25LL)	88.25

Table 3 GSA load attempt in NSA for irregular building with stepped elevation

Column removal case	**GSA loading condition**	**%GSA load attempt**
Column C1	2(DL + 0.25LL)	75.89
Column C2	2(DL + 0.25LL)	85.02
Column C3	2(DL + 0.25LL)	92.08
Column C5	2(DL + 0.25LL)	54.98
Column C6	2(DL + 0.25LL)	84.13

CONCLUSİONS:

The proposed approaches are compared with the observed data from analysis in this study to further assess accuracy and enhance the underlying assumptions and simplifications.

In this study, numerous structural geometries, positions for removing columns, and analytical approaches are all taken into account. To understand how employing varied bay sizes, atrium spaces, and imperfections on the model affects how stiff the structure is, this should also be researched.

High rise RC frame constructions are found to have stronger tendency to redistribute immediately after collapse and, as a result, to provide more resistance to progressive collapse. As the DCR value exceeded the allowable limits in accordance with GSA 2003 recommendations, maximum care should be paid to peripheral corner beam-column joint sections in lower floors above the collapsed column joint when designing progressive collapse resistant buildings. It is investigated how essential hinges arise in all constructions as a result of combating gravitational loads. This study's ultimate objective is to provide guidance on how to help stop the increasing collapse of structures.

REFERENCES :

[1] Buscemi, N., Marjanishvili, S.: SDOF model for progressive collapse analysis. In: Structures Congress 2005 (2005)
[2] Marjanishvili, S.M.: Progressive analysis procedure for progressive collapse. J. Perform. Constructed Facil. 18(2), 79–85 (2004)
[3] Shefna, L. S., Binu, P., Girija, K.: Progressive collapse analysis of a reinforced concrete frame building. Int. J. Civ. Eng. Technol. (IJCIET) 5(12), 93–98 (2014)
[4] Joshi, D. D., Patel, P. V., Tank, S. J.: Linear and nonlinear static analysis for assessment of progressive collapse potential of multistoried building. Structures
[5] Kim, J.: Assessment of progressive collapse resisting capacity of steel moment frames. J. Constr. Steel Res. 200901
[6] Karuna, S., Yashaswini, S.: Assessment of progressive collapse on a reinforced concrete framed building. Int. J. Emerg. Technol. Adv. Eng. 5(6) (2015)
[7] Ashna, T. E., Nivya J.: Progressive collapse analysis of regular structure. Int. J. Adv. Res. Eng. Manage. (IJAREM) 01(07), 90–95 (2015). http://ijarem.org/papers/v1-i7/13.pdf
[8] General Services Administration (GSA): Progressive Collapse Analysis and DesignGuidelines for New Federal Office Buildings and Major Modernization Projects. Office of Chief Architect, GSA, Washington, DC (2003)
[9] Sadek, F., Main, J.A., Lew, H.S., Bao, Y.: Testing and analysis of steel and concrete beam column assemblies under a column removal scenario. J. Struct. Eng. 137, 881–892 (2011)
[10] FEMA274: NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings. Federal Emergency Management Agency, Washington, DC (1997)

[11] Bhavik, R. P.: Progressive collapse analysis of RC buildings using non-linear static and non-linear dynamic method. Int. J. Emerg. Technol. Adv. Eng. 4(9) (2014)
[12] FEMA273: NEHRP Guidelines for the Seismic Rehabilitation of Buildings. Federal Emergency Management Agency, Washington, DC (1997)
[13] A.Marchis, M. Botez & A.M. Ioani. “Vulnerability to Progressive Collapse of Seismically Designed Reinforced Concrete Framed Structures in Romania”. 15 WCEE LISBOA 2012.
[14] General Service Administration. “Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects”, June 2003.
[15] G.Sukanya1, Dr.C.Natarajan2, Dr.A.Rajaraman. “Progressive Collapse Analysis of RC Beams”. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE e-ISSN: 2278-1684 Volume 5, Issue 4 (Jan. - Feb. 2013), PP 55-67.
[16] Miss. Preeti K. Morey, Prof S.R.Satone. “Progressive Collapse analysis of building” /International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 4, June-July 2012, pp.742-745 742 Page.
[17] “Criteria for earthquake resistant design of structures”. Part1 general provisions and buildings - (Fifth Revision) Indian Standard.
[18] “Code of practice for design loads (other than earthquake) for buildings and structures” part I & part II (Second Revision) (Incorporating IS: 1911-1967), (Reaffirmed 1997) Edition 3.1, (1997-12) Indian Standard.